ECON4910 Environmental Economics
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Problem set 6

Ex. 1. Supply-side policies.

This exercise is based on the model by Hoel (1994):

> As long as there is no international law to force countries to participate in an international climate agreement, each country may have an incentive to be a free rider, i.e., to stay outside the agreement instead of participating in it.
>
> (Hoel, 1994, p. 259)

Consider a carbon market for fossil fuels, that is competitive in the aggregate. Assume that all countries $i \in K$: both the net importers and the net exporters, are price takers and act independently:

x_i – Production of fossil fuels

y_i – Consumption of fossil fuels

where emission from country i is given by some function $E_i(x_i)$, i.e., emissions are heterogeneous in the way coal causes more emissions than natural gas (Golombek et al., 1995). Assume positive consumption ($y_i > 0$) and production ($x_i > 0$) to avoid corner solutions.

A group of countries experiences an environmental harm H from total emissions. They go together and cooperate on implementing environmental policies. They max total welfare of the whole group, hence, taking into account how their policy effect the international carbon market price when choosing their policy, such that the price becomes a function of the quantity: $p(y_i, x_i)$

$i = M$ – The cooperating countries

$i = N$ – The free riders

1. State the utility of the coalition, M.

2. State the utility of the free riders, N.

3. Derive the coalition's optimal tax on consumption y_M and production x_M

4. Derive the optimal emission tax if the supply industry in M must pay an emission tax that is proportional to the quantity it extracts, i.e., $t_x \equiv t_e E'_M(x_M)$. You can assume that $E''_M(x_M) \geq 0$, if you find this necessary. How does this tax depend on $E'_M(x_M)$?

5. How does it depend on $E'_i(x_i)$, $i \neq M$? Explain the intuition.

Ex. 2. Self-enforcing agreements

This exercise is based on the lecture note *Compliance technology and self-enforcing agreements*, by Harstad (2016). The purpose is to analyze how the society can succeed with climate treaties, taking into account the two challenges of self-enforcing and investments in green technology.

Consider a model with $i \in N = \{1, 2, ..., n\}$ countries that play the repeated prisoner's dilemma game, where countries apply grim trigger strategies. The utility/welfare of each country i is given by:

$$u_i = B(y_i) - C_i(g_i, g_{-i})$$

The benefit from consuming energy y_i is given by:

$$B(y_i) = \ln(b + y_i) \tag{1}$$

where $b \geq 1$ is some positive constant ensuring that the benefit function is well defined. Energy comes from two sources; fossil fuels g_i or renewable energy r_i:

$$y_i = g_i + r_i.$$

You can treat r_i as exogenously fixed for the time being. The variable g_i is a continuous variable. Using fossil fuels as the energy source creates a global negative externality, i.e., an environmental cost:

$$C_i(g_i, g_{-i}) = c_i \sum_{i=1}^{n} g_i \tag{2}$$

Consider a one period game, taking the level of r as exogenously give. Assume all countries are equal.

(1) What is the non-cooperative equilibrium, or the "business as usual" scenario in this game? Derive g_i^{BaU}

(2) What is the first-best equilibrium? Derive g_i^{FB}.

Consider now a repeated game, with $\delta \in (0, 1)$ as common discount factor.

(3) Suppose the equilibrium with g_i^{BaU} is the threat point which all countries revert to after a country has free-rided, in the repeated prisoner's dilemma game. Under which condition can the first best level for g be sustained? State the compliance constraint.

Consider now the scenario where where countries differ

(4) What is the non-cooperative equilibrium?

(5) What is the first-best equilibrium?

(6) State the compliance constraint.

Now, suppose the countries try to sustain a self-enforcing agreement with no pollution at all, $g_i^{\text{FB}} = 0$

(8) What is the condition for when this agreement is possible? State the new compliance constraint.

We now endogenize the technology levels by letting the countries simultaneously, non-cooperatively decide on their r_i's at the investment stage, which is prior to the emission stage. We introduce an investment cost kr_i, where the investment is made once and for all (before the repeated game starts, and never thereafter).

(9) Derive the optimal investment level, $\tilde{r}_i$.

References

Golombek, R., Hagem, C., and Hoel, M. (1995). Efficient incomplete international climate agreements. *Resource and Energy Economics*, 17(1):25–46.

Harstad, B. (2016). Compliance Technology and Self-Enforcing Agreements. Lecture note, University of Oslo.

Hoel, M. (1994). Efficient Climate Policy in the Presence of Free Riders. *Journal of Environmental Economics and Management*, 27(3):259–274.